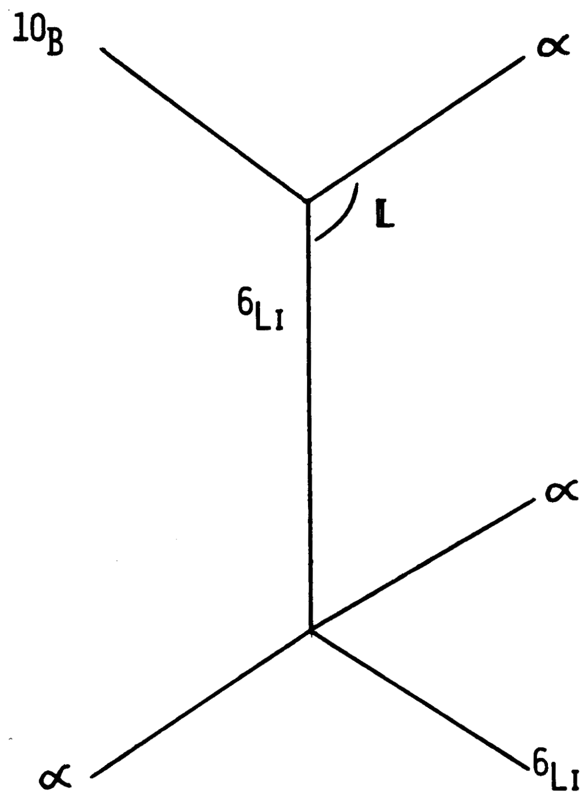

Figure 3. Pole graph representing the $^{10}B(\alpha,^{6}Li\alpha)\alpha$ quasifree scattering of $^{6}Li + \alpha$.

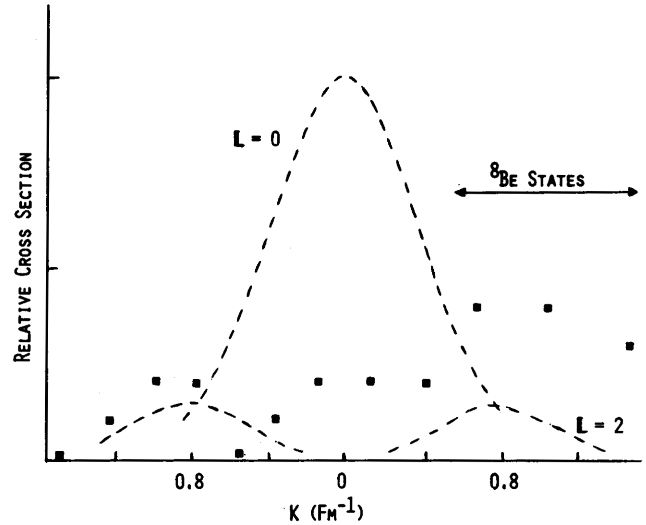

Figure 4. Data and PWIA predictions with L=0 and L=2 as a function of transferred momentum. In the PWIA calculation, the free cross section was assumed to be constant.

SEARCH FOR 3p-3h STATES IN THE A=16 SYSTEM

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Recently there has been considerable interest, both experimentally and theoretically, in the location of three particle-three hole (3p-3h) states in the A=16 system. The most direct evidence that a given state has a predominant 3p-3h configuration comes from three-nucleon transfer data where this state is strongly populated. In addition such states are only weakly excited in simpler reactions involving the transfer of one or two nucleons.

We have embarked on a program to search for 3p-3h states in ^{16}N-^{16}O with the (^{6}Li,^{3}He) and (^{6}Li,t) reactions on ^{13}C at a bombarding energy of 99 MeV. For the purpose of comparison the (^{6}Li,^{3}He) and (^{6}Li,t) reactions on ^{12}C were also measured under identical conditions.

Figure 1 shows spectra of the $^{13}C(^{6}Li,^{3}He)^{16}N$ and $^{13}C(^{6}Li,t)^{16}O$ reactions at an angle of 15°. States in ^{16}O at 6.13, 11.09, 14.40, 14.80, 20.80, and 24.80 MeV and states in ^{16}N at 7.65, 9.81, 11.21, and 11.81 MeV are strongly populated. Analogue pairs of states are clearly seen. The strong group of states at 14.40 and 14.80 MeV in ^{16}O has no counterpart in the ^{16}N

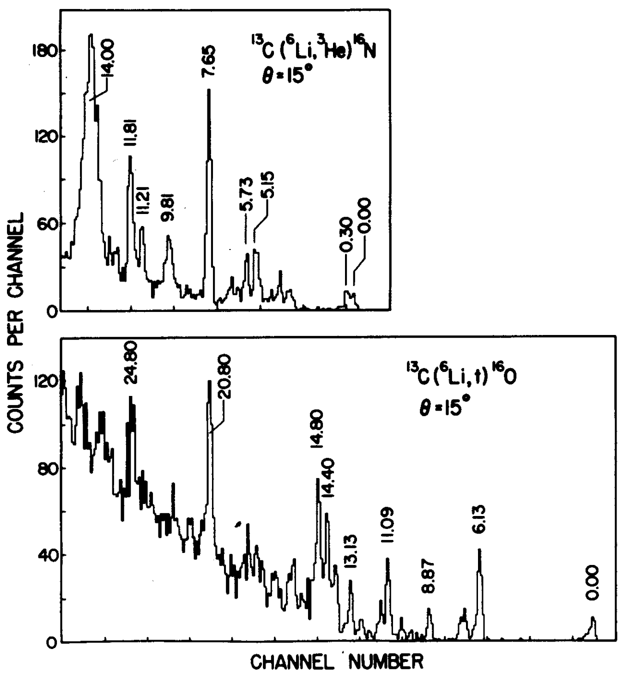

Figure 1. Spectra for the $^{13}C(^{6}Li,^{3}He)^{16}N$ and $^{13}C(^{6}Li,t)^{16}O$ reactions at a ^{6}Li bombarding energy of 99 MeV and a laboratory angle of 15° taken with a solid-state detector telescope.

spectrum, thus suggesting a T=0 assignment.

Since the ground state of ^{13}C can be described in first order as $(p_{1/2})^{-3}$ with respect to ^{16}O as a core, the transfer of three nucleons in the $[(p_{1/2})^{2}d_{5/2}]$, $[p_{1/2}(d_{5/2})^{2}]$ and $(d_{5/2})^{3}$ configurations can lead to 1p-1h, 2p-2h, and 3p-3h final states of the $[p_{1/2}{}^{-1}d_{5/2}]$, $[(p_{1/2})^{-2}(d_{5/2})^{2}]$, and $[(p_{1/2})^{-3}(d_{5/2})^{3}]$ configurations, respectively. Due to momentum mismatch, the high-spin states of these configurations are expected to be strongly excited. The 1p-1h and 2p-2h configurations should also be strongly excited in the simpler one- and two-nucleon transfer reactions.1-3)

In the weak coupling model, the level spacing of the 3p-3h states in ^{16}N-^{16}O are the same as those for the 3p-4h states in ^{15}N-^{15}O and for the 3p states in ^{19}F-^{19}Ne. Figure 2 shows excitation energies of 3p-4h states in ^{15}N-^{15}O and 3p states in ^{19}F together with the corresponding 3p-3h states in ^{16}N-^{16}O as suggested by the present experiment. The coupling of the transferred three nucleons in the $(d_{5/2})^{3}{}_{J=9/2}$ and $(d_{5/2})^{3}{}_{J=13/2}$ configurations to the ground state of ^{13}C as a core results in two doublets of spins $4^{-},5^{-}$and $6^{-},7^{-}$. The resolution in the present experiment (~ 200 keV) was not good enough to separate these two doublets. Additional evidence that the 7.65 and 11.81 MeV states in ^{16}N and the 20.80 and 24.80 MeV states in ^{16}O are predominantly of the 3p-3h configuration comes from the comparison to one-and two-nucleon transfer data to these states. All of them are, if at all, only weakly excited in one-nucleon transfer reactions.1) In the $^{14}N(\alpha,^{2}He)^{16}N$ reaction,3) levels at 6.62 and 7.69 MeV (unresolved doublet) were most strongly populated and have been interpreted as $[^{14}N(g.s.,1^{+}) \otimes (d_{5/2})^{2}{}_{J=4}]$ 2p-2h configuration states. We concluded that the 7.65 MeV state observed in the present $^{3}C(^{6}Li,^{3}He)^{16}N$ reaction is not identical to the 7.69-MeV 2p-2h doublet, since the 6.62-MeV 2p-2h state of the same configuration would also have to be excited quite strongly and we see no evidence for its formation.

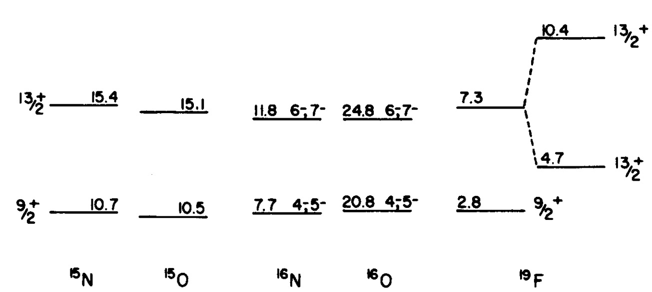

Figure 2. Excitation energies for 3p states in ^{19}F, 3p-3h states in ^{16}N-^{16}O, and 3p-4h states in ^{15}N-^{15}O.

1) F. Ajzenberg-Selove, Nucl. Phys. A281, 1 (1977).

2) M.S. Zisman, E.A. McClatchie, and B.G. Harvey, Phys. Rev. C2, 1271 (1970).

3) R. Jahn, D.P. Stahel, G.J. Wozniak, R.J. de Meijer, and J. Cerny, Phys. Rev. C18, 9 (1978).

STUDY OF THE (^{6}Li,^{8}B) REACTION IN THE Zr REGION

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Using the 90-MeV ^{6}Li beam at IUCF, we have studied the reactions ^{92,94,96,98,100}Mo(^{6}Li,^{8}B)^{90,92,94,96,98}Zr and also the reactions ^{90,92,94}Zr(^{6}Li,^{8}B)^{88,90,92}Sr. These investigations had a twofold objective, first to study two-proton configurations in the Zr region and, second to examine the usefulness of the (^{6}Li,^{8}B) reaction as a spectroscopic tool.

The ^{8}B ions were momentum analyzed by the IUCF QDDM magnetic spectrograph and detected by a gridded ionization chamber[1]. Spectra were recorded at $\theta_{lab} = 8°$ for all targets. Because ^{7}B and ^{9}B are proton unstable, ^{8}B is particularly easy to identify in a detector of this type and was well separated from other ion species in the E-ΔE spectra.

The experimental results obtained from bombardments of the Mo targets are shown in Fig. 1. Focusing attention on the $0^+ \rightarrow 0^+$ transitions to the ground states (g.s.) and the first excited 0^+ states (0^+_2) in Zr, one immediately notices a pronounced dissimilarity between the ^{96,98}Zr spectra and the spectra of the three lighter-mass isotopes. For instance, in ^{98}Zr the 0^+_2 transition is twice as intense as that to the g.s., while in ^{90}Zr the reverse is true with the 0^+_2 transition having only a quarter of the g.s. strength.

The explanation for this variation in 0^+_2 strength relative to that of the g.s. can be traced to changes in the Zr proton configurations with neutron number. To provide a theoretical prediction of the $0^+ \rightarrow 0^+$ transition strengths observed for the five Mo targets, we have carried out exact finite-range distorted-wave Born approximation (EFR DWBA) calculations using the code DWUCK5[2]. The calculation assumes the reaction consists of a direct, one-step cluster transfer of a T=1, S=0 proton pair. The code was used to calculate the ratio of the cross sections for the 0^+_2 states to those of the ground states for each of the five Zr isotopes. The proton configuration of the Zr ground states was assumed to be of the form $\alpha(p_{1/2})^2 + \beta(g_{9/2})^2$. The 0^+_2 states were taken to be the orthogonal states $\beta(p_{1/2})^2 - \alpha(g_{9/2})^2$. The neutrons were assumed to be inert. Except for ^{98}Zr, where they were adjusted to yield exact agreement with experiment, the amplitudes α and β used in the EFR DWBA calculations were the same as those determined from single-proton pickup[3] and stripping[4] data and are based on averages of the experimentally obtained values given in Table 13 of Ref. 4.

A comparison of the calculated and experimental ratios is given in Table 1, where it can be seen that the agreement is quite good. This suggests that the Zr wave function amplitudes and the simple reaction model we have used are basically correct.

The results obtained from the three Zr targets are